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Innovation and Competition: The Role of Finance Constraints in a Duopoly Case

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Abstract. In this paper we analyse the role of financial resources in a process of competition interpreted as a continuous restructuring of productive capacities. Financial constraints appear an essential means of co-ordination. Co-ordination with the environment where this process of restructuring takes place for the process itself to be viable and co-ordination between firms for the survival of competition.

Key Words: competition, co-ordination, finance, innovation

JEL classification: L11, O31.

1. Introduction

In this paper we intend to explore the nature of the relation between competition and innovation—which is the most effective way to acquire a competitive advantage on the market—and to stress the particular trade-off that characterizes this relation.

In particular, we will show, with reference to a very simple duopoly market, that incentives exist which conduce firms to choose strategies that make it possible to take advantage of potential increasing returns of innovation as determined by the cost reductions associated with a continuous restructuring of productive capacities.

In this perspective, we shall contrast the view of competition as a process with the prevailing view of competition as an equilibrium state characterized by an atomistic or oligopolistic market structure. Viewed as a process, competition has very little to do with the number of firms which compete on the market. It appears in fact as the co-ordination mechanism by which *potential returns* are actually transformed into *monetary gains* to the benefit of firms, workers and consumers; and, as such, it can be adequately analyzed irrespective of the number of firms involved in this process.

Co-ordination is required to take care of the structural effects which innovation implies. However, it would be a mistake to focus directly on the new productive capacity that

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incorporates the new technology when it is ready to be used, that is when production costs, defined without any reference to their time dimension, have been effectively reduced. Innovation is a process. The productive capacity that incorporates the new technology must be built before it can be used, and its construction needs time. As we shall see, the main aspect of innovation processes is that there is never a complete synchronisation between construction and utilization. Consequently, a divorce appears along the way between costs and proceeds, that actually determines the competitive position of the firms. This actually depends on their strategic choices as determined by the resource constraints inherited from the past which affect step by step costs and prices.

In this view, competition cannot be reduced to price competition à la Bertrand or quantity competition à la Cournot given the cost conditions. As a matter of fact, both prices and quantities reflect production costs and capacity constraints which change step by step during the process of restructuring of productive capacity through which innovation is brought about.

Financial constraints appear as an essential means to deal with the co-ordination problems between competing firms, and of the firms themselves with the environment, which arise during these restructuring processes.

2. The Meaning of Competition

Competition is usually looked at as a descriptive term characterizing a particular state of affairs. In defining this state of affairs the focus is on a market structure, namely a competitive market, where 'perfectly competitive' implies the existence of an infinitely large number of firms.

In this view, competition appears as a *state*, interpreted as an equilibrium situation determined, via a principle of rational behaviour, by essentially exogenous 'fundamentals' that include given cost conditions and information structures.¹

The distinction between perfect and imperfect competition hides the uniqueness of an approach which focuses on established fully co-ordinated states of the economy although corresponding to different cost conditions and information contexts and hence to different behaviours. In the case of oligopolistic competition, a strategic interaction takes place which however does not affect the consistency of the production plans of the firms so as to result in a market disequilibrium

Reference to the market has always been central to the definition of the concept of competition. However, classical economists, who originated this concept, viewed competition "as a price-determining force operating in, but not itself identified as, a market" (McNulty 1968:644). The focus was on patterns of business behaviour—in particular, behaviours like price undercutting by sellers, bidding up of prices by buyers, entry of new firms or exits from the market, and the like. In this view, what is stressed is a *process* made up by competitive behaviours, rather than the effects of a competitive process, as revealed by a *state*. Thus the classical concept of competition, focusing on market activity seen as a process, was a *disequilibrium* concept, while perfect competition seen as a market structure is an *equilibrium* situation.

But although classical economists saw competition as a process, this was viewed as entirely a phenomenon of exchange in the sense that buying or selling appeared as the critical

element of economic activity, and the fixing of prices its main expression. Competition, in other words, was not related in a proper way to the phenomenon of production, itself looked at from the vantage point of trade and exchange. Changes in techniques or in the industrial organization—the ‘division of labour’—were “limited by the extent of the market, so its analysis in terms of the organization of production within the business firm came to be circumscribed, even for Adam Smith, by the analysis of the firm’s external market relationships. Not the essence of the industrial revolution—the changing mode of production—but rather, the mercantilists’ overriding concern with price, continued to be the central theme of economic analysis” (McNulty *ibid.*:648).

The only reference to production is represented by the reference to given cost conditions as determined by the size of the market. This implies a predetermined definition of the market structure which pushes into the shade the process leading to it. The successive refinements of neo-classical economists led eventually to the abandonment of the reference to a process and the full identification of the concept of competition with a given market structure.

3. Competition as a Process

To go back from the definition of competition as a state to the analysis of competition as a process implies to look no longer at given data (the ‘fundamentals’) which determine (univocally or less) the (equilibrium) values of the variables of the economy that define a competitive state. The ‘fundamentals’ which determine competitive equilibrium relations, we have already mentioned, are essentially given information structures and cost conditions. Hence competition appears as the process by which information is acquired and costs are determined.

Hayek (1937, 1948) moved a first step in the direction of the reconsideration of competition as a process by hinting at the problem of changing information associated with the evolution of technology and preferences. In fact, he defined competition as a learning process, namely, a process of discovery of the relevant information. Market information—the information concerning price, quantity and quality of goods and services—does not pre-exist the process of competition, as with the models of the Cournot–Walras type, but is a problem the solution of which is brought about exactly by the competition process.

We intend to complement the analysis by also considering the other aspect of the problem: the changes in cost conditions. We shall do this by focussing on what actually determines cost conditions: the ‘changing mode of production’ overlooked also by classical economists. This implies to stress a characteristic of the phenomenon of production which, as we shall see, is essential for portraying competition as a process, that is, the time dimension of production processes. As a matter of fact changes in cost conditions result from a restructuring of productive capacity which can only take place through a process in time.

Competition implies a restructuring of productive capacities which is the essence of innovation. This is why the process of competition is best analyzed with reference to the innovation process, to which it is strictly related. On the other hand innovation is characterized by a continuous feedback between technology and the environment. The appearance of a new technology implies the breaking up of the existing industrial structure and a

modification of the market conditions. It brings about a gradual reshaping which reflects the scarcities encountered on the way, the particular effort made to overcome these scarcities, the changes in cost conditions, in profitability and in relative prices, the modifications of the consumers' preference system, and all the other events that represent the specific episodes that mark the profile of the process of innovation. The behaviour of competing firms is essential in determining these episodes and hence what this profile will actually be.

The analysis of the process of innovation calls for a shift of focus from the production decisions of the firms concerning the utilization of a given productive capacity to the investment decisions in the sense of construction of this productive capacity.

In conclusion, competition appears as a process which walks both on the leg of imperfect information and on that of the time dimension of production, and which is fed by the sequential interaction of competing firms.

The analysis developed along these lines will make it possible to show that the process of competition is associated with problems of co-ordination which *originate within the firms*, namely, in their production side—and therefore take the form of problems of intertemporal coordination—and then extend to the relation *between firms*.

Money (financial resources) is a crucial element in this process. It is an essential constraint to the decisions of firms which emerges as the result of the appearance of co-ordination problems in a dynamic context, and as such it contributes to determine the shaping out of the competition process.

4. Innovation, Sunk Costs and Competition

The co-ordination problems implied by innovation consist mainly in dealing with the sunk costs associated with a restructuring of productive capacities. These are the costs of fixed capital or of R&D, advertising and the like, that is, are the construction costs of new productive capacities. The focus on sunk costs is common to the New Industrial Organization approach (NIO), but the role we attribute to them is quite different.

In the NIO “a fascinating aspect of sunk costs is their commitment value” (Tirole 1988:314). This commitment refers to a multi-period context and represents a credible threat which is essential to the determination of market structure. However, the sunk costs depend in turn on market structure and are determined simultaneously with the latter. This is so because the sunk costs are determined once the market game which defines the market equilibrium is known. Everything is defined following a backward induction process which implies an analytically instantaneous determination of all the relevant magnitudes. A less extreme version of NIO is that of Sutton (1991, 1998) who abandons the aim of identifying some unique equilibrium outcome in a given multi-period context. “Instead we admit some class of candidate models (each of which may have one or more equilibria) and ask whether anything can be said about the *set* of outcomes that can be supported as an equilibrium of any candidate model” (1998:6–7) This set of outcomes must satisfy two conditions: the viability condition—which means that each firm covers its sunk cost over the multi-period domain—and the stability condition—which allows to preserve a certain structure of the market.

Although essentially different our treatment of sunk costs has some relation to Sutton's analysis. This concerns the focus on *viability* and its relation to market structure. However,

sunk costs, in our analysis, are the expression of a breaking of the intertemporal complementarity of the production process as the result of the attempt to carry out an innovation. Intertemporal complementarity is the main feature of a process of production where the relation between the phase of construction and that of utilization of productive capacity is stressed. When this complementarity is no longer assured costs are dissociated in time from proceeds and hence become ‘sunk’ costs. The characteristic of the sunk costs of the investment in a process which implies a structural change is that they will only be recovered when (and if) the process itself is actually established. This means not only to take into account the whole period of construction of the new productive capacity—which is likely to have a considerable length as, before construction in a proper sense, it implies experimenting, pilot plans, and so forth—but to go further beyond that point, until the stream of receipts from the new output has reached a certain size and the change has thus proved viable.

In this context the irreversibility of investment together with an incomplete information prevent any solution based on backward induction; hence investment decisions are not necessarily consistent with the working of the market. Market structure depends on the working of the co-ordination mechanisms and is *actually* the outcome of a process sketched out by the way sunk costs are sequentially dealt with. The viability of this process, and the resulting market structure considered, depend exactly on how we are able to deal with this sort of ‘sunk’ costs. Financial resources—and in particular the existence and the strength of financial constraints—play an essential role in this, as they determine the way in which investment decisions are *actually carried out* and hence whether the productive capacities brought about are consistent or less with the existing environment.

Finally, an important difference with the NIO approach must be stressed. In this approach the market game that determines both the market structure and the associated sunk costs is in the nature of a choice. The focus is therefore on an incentive scheme which allows to make this choice.

On the contrary the problem we address has not the character of a choice. What matters is the viability of a process which builds up step by step and does not depend on a marked game solved beforehand. In this light the focus is on the conditions that make this process viable rather than on incentive schemes relevant for a choice.

5. A Neo-Austrian Model

We present here a model derived from Amendola and Gaffard (1998) which makes it possible to exhibit the time structure of production processes and to analyze the sequential interaction of competing firms in a process of restructuring of productive capacities.

In the usual way the system is described by state variables and control variables. The state variables, in the modelling proposed, are for each firm ($i = 1, 2$):

$x(t)$, the vector of production processes,
 $m(t)$, the money proceeds from sales,
 $h(t)$, the monetary idle balances,
 $o(t)$, the stock of final output,
 $\omega(t)$, the wage fund,

$d(t)$, the volume of final demand,

$\delta(t)$, the market share.

The control variables are:

$x_1(t)$, the rate of starts of production processes,

$u(t)$, the rate of scrapping of production processes,

$\tau(t)$, the rate of utilization of productive capacity,

$p(t)$, the price of final output,

$w(t)$, the wage rate,

$f(t)$, the external financial resources which depend on banking policy,

These are either determined exogenously in the simulations (the open-loop control variables) or according to feedback mechanisms (the close-loop control variables).

In each firm i production is carried out by means of processes of a Neo-Austrian type. An elementary process of production is defined by the input vector:

$$\mathbf{a}_j^i = [a_{jk}^i]; \quad k = 1 \dots n^c + n^u$$

whose elements represent the quantities of labour required in the successive periods of the phase of construction from 1 to n^c and following it, of the phase of utilization (from $n^c + 1$ to $n^c + n^u$) of the productive capacity of commodity (technology) j , so that:

$$\mathbf{a}_j^i = [\mathbf{a}_j^{ic}, \mathbf{a}_j^{iu}]$$

with $a_{jk}^{ic} = a_j^{ic} \forall k = 1, \dots, n^c$ and $a_{jk}^{iu} = a_j^{iu} \forall k = n^c + 1, \dots, n^c + n^u$, and by the output vector:

$$\mathbf{b}_j^i = [b_{jk}^i]$$

with $b_{jk}^{ic} = 0 \forall k = 1, \dots, n^c$ and $b_{jk}^{iu} = b_j^{iu} \forall k = n^c + 1, \dots, n^c + n^u$

At each given moment t the productive capacity of a commodity j by a firm i is represented by the intensity vector:

$$\mathbf{x}_j^i(t) = [\mathbf{x}_j^{ic}(t), \mathbf{x}_j^{iu}(t)]$$

each element of which is a number of elementary production processes of a particular age, still in the construction phase or already in the utilization phase.

Scrapping of production processes $u(t)$ occurs when resource constraints are as stringent as not to allow all the processes inherited from the past to be carried on. An alternative to scrapping is a partial use of utilization processes, which, however, implies a cost, as we shall see when considering the rate of utilization of existing productive capacity.

In what follows the productive capacity of each firm at each given moment will be described by the vectors $\mathbf{A}^i(t)$, $\mathbf{B}^i(t)$ and $\mathbf{x}^i(t)$ the elements of which are the quantities of

labour, the quantities of output and the number of processes respectively, referring to all the commodities produced (the technologies in use) by each firm:

$$\begin{aligned} \mathbf{A}^i(t) &= [A_k^i(t)] \quad \text{with } k = 1, \dots, n^c + n^u \\ \mathbf{B}^i(t) &= [B_k^i(t)] \quad \text{with } k = 1, \dots, n^c + n^u, \quad \text{where } B_k^i(t) = 0 \quad \forall k = 1, \dots, n^c \\ \mathbf{x}^i(t) &= [\mathbf{x}^{ic}(t), \mathbf{x}^{iu}(t)]. \end{aligned}$$

In each period the level of activity (both investment and current production) of the firms, which depends on the wage fund $\omega^i(t)$ is constrained by available financial resources or, alternatively, by available human resources.

The available financial resources $F^i(t)$ are:

$$F^i(t) = m^i(t-1) + h^i(t-1) + f^i(t)$$

where the internal financial resources are given by $m^i(t-1)$, the money proceeds from the sales of final output, and $h^i(t-1)$, the idle money balances involuntarily accumulated in the past and ready for use, and the external financial resources by $f^i(t)$.

The available human resources are:

$$\psi^i(t) = (1 + g)^t L^i(0) w^i(t)^\vartheta$$

where g is the natural growth rate and ϑ the wage elasticity of the labour supply.

This means that the supply of labour to all firms resulting from the natural growth of the labour force can be increased (or reduced) by each firm through changes in the wage rate that it pays. A general human constraint may appear due to an insufficient growth of the labour force. This constraint can be relaxed by each firm through the wage policy followed, but not completely, due to the assumption of an imperfect mobility of workers between firms.

When the human constraint is more stringent than the financial constraint money balances are involuntarily accumulated:

$$h^i(t) = \max[0, F^i(t) - \omega^i(t)].$$

Within the sequential setting considered prices are fixed within each given period and can only change at the junction of one period to the next one. As a consequence we have:

$$m^i(t) = \min[p^i(t)d^i(t), p^i(t)s^i(t)].$$

Real stock changes are substitutes for the price changes, which cannot take place within the period. Excess supply results in an accumulation of undesired stocks for the firm:

$$o^i(t) = \max[0, s^i(t) - d^i(t)]$$

where $s^i(t)$ and $d^i(t)$ are current real supply and real demand (for the different and successive commodities or technologies), respectively.

Current final production by firm i will then be:

$$q^i(t) = s^i(t) - \eta o^i(t-1), \quad 0 \leq \eta \leq 1$$

which is also equal to:

$$q^i(t) = \tau^i(t) \sum_{k=n^c+1}^{n^c+n^u} B_k^i(t) x_k^i(t)$$

$\tau^i(t)$ being the rate of utilization of the productive capacity inherited from the past. Coefficients $B_k^i(t)$, as we have seen, are the output coefficients which refer to the different technologies in use at period t .

The aggregate market demand, D , is determined as follows:

$$D(t) = (1 + \hat{g})D(t-1)p^\theta, \quad \theta \leq 0$$

that is, it depends on the average market price, given an exogenously determined growth rate \hat{g} .

The average market price is given by:

$$p(t) = \frac{\sum_i p^i(t)s^i(t)}{\sum_i s^i(t)}.$$

The market shares are:

$$d^i(t) = \delta^i(t)D(t)$$

with:

$$\delta^i(t) = \frac{\frac{\delta^i(t-1)}{p^i(t-1)}}{\sum_i \frac{\delta^i(t-1)}{p^i(t-1)}}$$

that is, a firm's market share depends on the relation of its price to the average market price in the preceding period.

The evolution path followed by each firm is actually determined by the behaviour of the decision variables, namely, the rate of starts of new production processes $x_1^i(t)$, the rate of utilization of productive capacity $\tau^i(t)$, the price of final output $p^i(t)$, the wage rate $w^i(t)$, the ratio k^i of the external financial resources $f^i(t)$ to the money proceeds from the sales of final output $m^i(t)$ (i.e., the firm's borrowing power), and the rate of scrapping $u_k^i(t)$.

Each firm determines the rate of starts of production processes in such a way that the productive capacity available $n^c + 1$ periods later will match a final demand which is

expected to be equal to the current one multiplied by a growth factor $1 + \gamma$:

$$x_1^i(t) = \max \left[0, \frac{d^i(t-1)(1 + \gamma^i(t-1))^{n^c+1} - \bar{\tau}^i \sum_{k=1}^{n^u-1} \tilde{b}_{k+n^c}^i(t-1)x_k^i(t-1)}{\bar{\tau}^i \tilde{b}_{n^c+1}^i} \right]$$

where $\gamma^i(t-1)$ is the growth rate of the final demand expected by the firm i at $t-1$ (which is determined as a weighted mean of the growth rates registered in the previous periods), and $\bar{\tau}^i$ is the desired rate of utilization of productive capacity. Different investment behaviours may be considered by introducing more or less stringent limits to the variations of the *desired* rate of starts from one period to the next: limits which represent more or less aggressive investment behaviours.

Each firm determines current production by fixing the current rate of utilization of its productive capacity, $\tau^i(t)$, so as to adjust its current supply to the expected final demand $\hat{d}^i(t)$:

$$\tau^i(t) = \min \left[1, \frac{\hat{d}^i(t) - (o^i(t-1) - o_d^i(t))}{\sum_{k=1}^{n^c+n^u} B_k^i(t) x_k^i(t)} \right]$$

where $\hat{d}^i(t)$ is such that:

$$\hat{d}^i(t) = \frac{m^i(t-1)^2}{p^i(t)m^i(t-2)}$$

that is, the expected final demand is made to depend on the past trend of money proceeds of the firm, and $o_d^i(t)$ are the stocks that the firms desire to keep.

As the result of the production and investment decisions the actual wage fund is given by:

$$\omega^i(t) = w^i(t) \Lambda^i(t)$$

where $\Lambda^i(t)$ is the labour demand given by:

$$\Lambda^i(t) = \sum_{k=1}^{n^c+n^u} A_k^i(t) x_k^i(t) \rho_k^i(t)$$

where ρ^i is a vector which allows to take into account what are the consequences on the labour demand of a variation in the rate of utilization of the productive capacity:

$$\rho^i = [\rho_1^i, \dots, \rho_{n^c+n^u}^i]$$

with $\rho_k^i = 1$ for all $1 \leq k \leq n^c$ and $\rho_k^i = \tau^i(t) + \zeta^i(1 - \tau^i(t))$ for all $n^c + 1 \leq k \leq n^c + n^u$ where ζ^i stands for the labour required to maintain a process of production idle.

The price charged by each firm is determined as follows:

$$p^i(t) = \frac{w^i(t) \sum_{k=1}^{n^c+n^u} a_{jk}^i \rho_k^i}{\bar{\tau}^i \sum_{k=n^c+1}^{n^c+n^u} \hat{b}_k^i}$$

with $\rho_k^i = 1$ for all $1 \leq k \leq n^c$ and $\rho_k^i = \bar{\tau}^i(t) + \zeta^i(1 - \bar{\tau}^i(t))$ for all $n^c + 1 \leq k \leq n^c + n^u$

That is, it is determined in such a way as to cover the cost of production when using the productive capacity which is the expression of the technology adopted, at the desired rate of utilization of this productive capacity. This price is determined step-by-step with reference to the new technology adopted each time, at the moment this first reaches the phase of utilization. This is how price competition is implemented by each firm.

Changes in the wage rate paid by each firm reflect the disequilibria arising on its labour market, that is:

$$w^i(t) = \left(1 + v^i \frac{\Lambda^i(t) - \psi^i(t-1)}{\psi^i(t-1)}\right) w^i(t-1)$$

where v^i is a reaction coefficient.

As already mentioned firms are wage makers on local labour markets. However competition between firms results in different but convergent wage rates charged by each of them.

External financial resources are such that:

$$f^i(t) = \min[k^i m^i(t), f_d^i(t)]$$

where k^i stands for the borrowing power of each firm, and $f_d^i(t)$ is the demand for external financing resulting from the production and investment decisions actually taken.

Financial constraints are formally exogenous in the model. Different financing scenarios which imply to consider the relation between external finance and the viability of innovation processes have been explored. An interpretative step forward can be made by inferring that when positive results of the simulations are associated with a specific value of k^i , such a value will express the opinion (and the decisions) of financial markets and/or of bankers.

Finally, the prevailing resource constraints determine the rate of scrapping of production processes.

The performance of each firm is measured by its unit margins, whereby a unit margin is defined, in each period, as the ratio of the difference between the price (calculated as mentioned above) and the current unit cost of output—obtained by dividing the total cost of production of the amount of output obtained in that period by the same amount—to the price itself:

$$\mu^i(t) = \frac{p^i(t) - c^i(t)}{p^i(t)}$$

where

$$c^i(t) = \frac{w^i(t) \Lambda^i(t)}{q^i(t)}.$$

Unit margins on average equal to zero mean that firms realize normal profits. Unit margins will be instead necessarily negative at the beginning of any innovation process characterized by higher construction costs. This reveals the initial competitive disadvantage suffered by the innovative firm. On the other hand, negative unit margins may also reveal the existence of excess capacities, that is, of a lower degree of utilization of productive capacity with respect to the desired level, and vice-versa.

6. The Process of Competition: A Simulation Analysis

In this section we report and analyze the results of simulation experiments performed by making use of the model presented in the previous section. These experiments are mainly aimed at understanding in which conditions technical increasing returns are actually transformed into monetary gains and whether these gains accrue to firms, workers and/or consumers. We shall focus on the effects of financial constraints, in relation with the frequency of innovations, on the unit margins.

We shall deal with the case in which technological improvements are successively introduced by the firms considered. These technological improvements are forward biased in Hicks' terminology (1973) but not in the same sense: increasing construction labour costs (a^c) are more than compensated not by decreasing utilization labour costs (a^u)—as with Hicks—but by increasing output rates (b). This introduces increasing returns.

In the simulations two innovative firms ($i = 2$) compete with each other through changes in prices which reflect changes in productivity due to changes in technology and changes in wage rates.

Competition has a sequential character: the firms innovate one after the other. At the beginning of the experiment both firms have an equal share of the market (50% each) and face an aggregate final demand which increases at an exogenously given rate but also depends on the average market price of final output. We assume that the firms take investment decisions looking at the expected demand. In doing so they discount the increases in productivity resulting from their own innovations but not those realized by the competitors.² This is likely to bring about productive capacities in excess with respect to the existing demand and pushes the competing firms to try to steal market shares from each other (capacity competition). However the firms also know that the volatility of investments is a threat to their survival. We shall therefore assume in the simulations that the change in the rate of starts of new production processes (whether an increase or a decrease) from one period to the next is limited to 5%, which results in a weak 'capacity competition'.

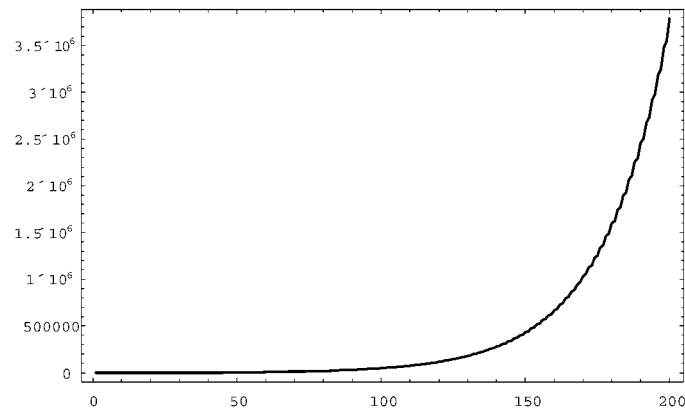
The changes in prices through which the competition takes place reflect changes in costs. As we have just mentioned, the changes in costs result in the first place from the modifications in the structures of productive capacities due to the innovation process, whose viability in turn, as we shall see, essentially depends on the prevailing financial constraints. On the other hand, the changes in costs also reflect an endogenous dynamics due to wage changes.

Let us start by considering a case characterized by innovations that take place every four periods ($F = 4$), a strong external financial constraint ($k = 0.05$), and a weak wage flexibility ($v = 0.001$). In this case there are small fluctuations in market shares and both firms remain on the market (Figures 1). In letting wages to react to changes in the conditions

of labour markets in a context characterized by a small growth rate of the labour force, we introduce an endogenous dynamics of costs. Pressures on their own labour markets depend on the investment decisions of the firms. Thus the attempt of a firm to increase its productive capacity in order to gain a higher market share results in a greater demand for labour, a higher relative wage, and a higher relative price, which should actually result in a decreasing market share. However, a human resource constraint inevitably appears along the way. This checks the evolution of the rate of starts, which, together with the limited wage flexibility, reduces the fluctuations of costs around a decreasing trend. This is the reason of

Parameters	First shock	F	k	n	ν
Firm 1	5	20	0.3	10	0.001
Firm 2	15	20	0.3	10	0.001

Global Demand



Real Demand (Actual and Expected)

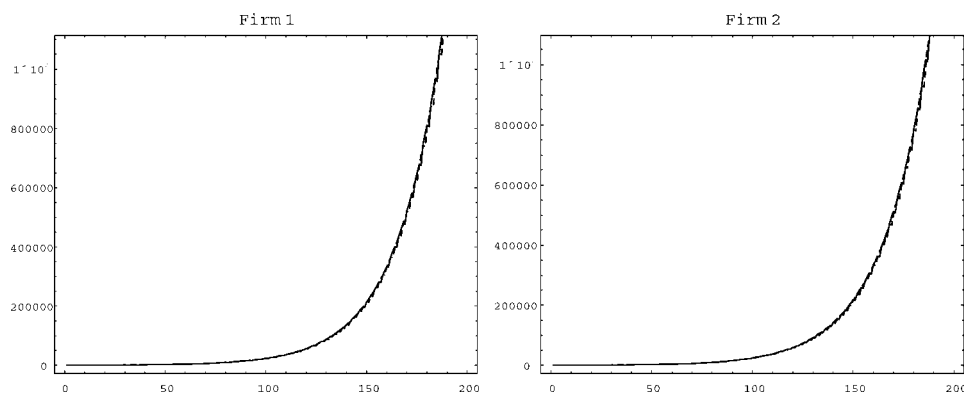
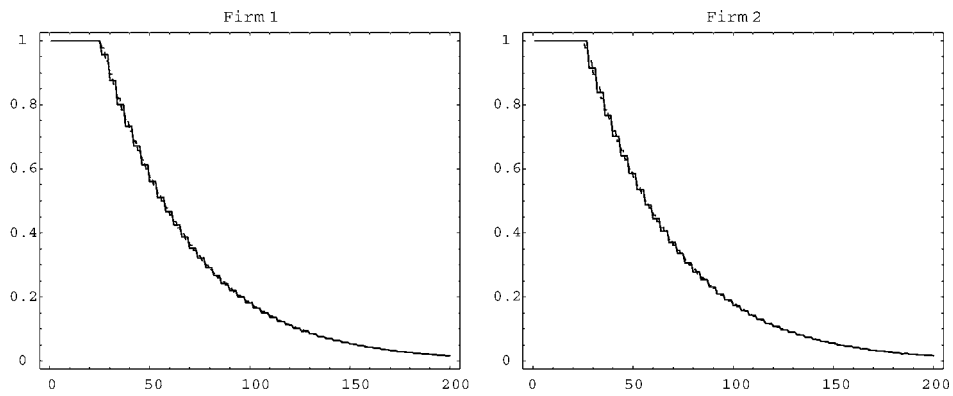
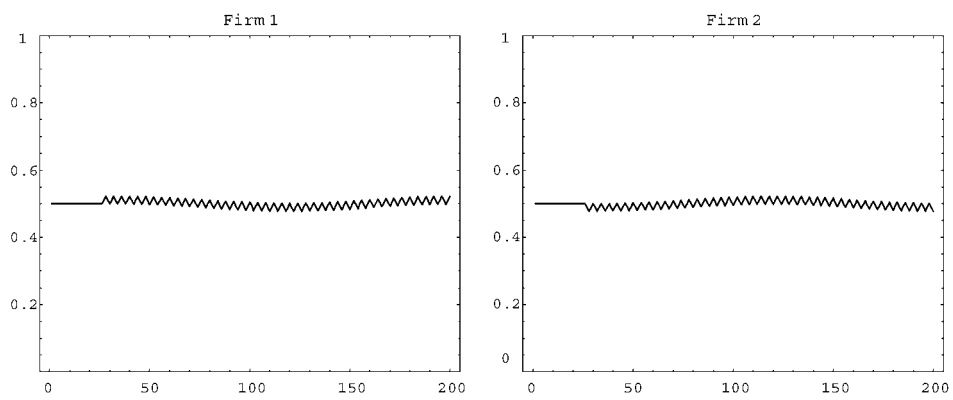
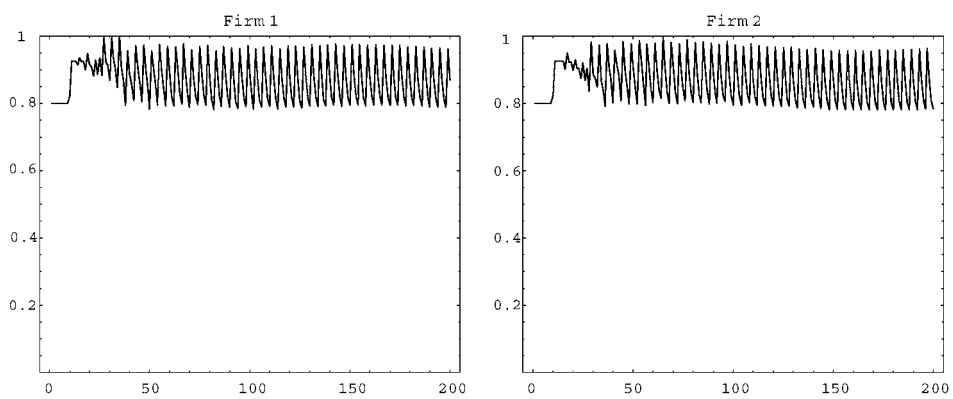


Figure 1.

(Continued on next page.)

Price and Average Price**Market Shares****Rate of Capacity Utilization***Figure 1. (Continued).*

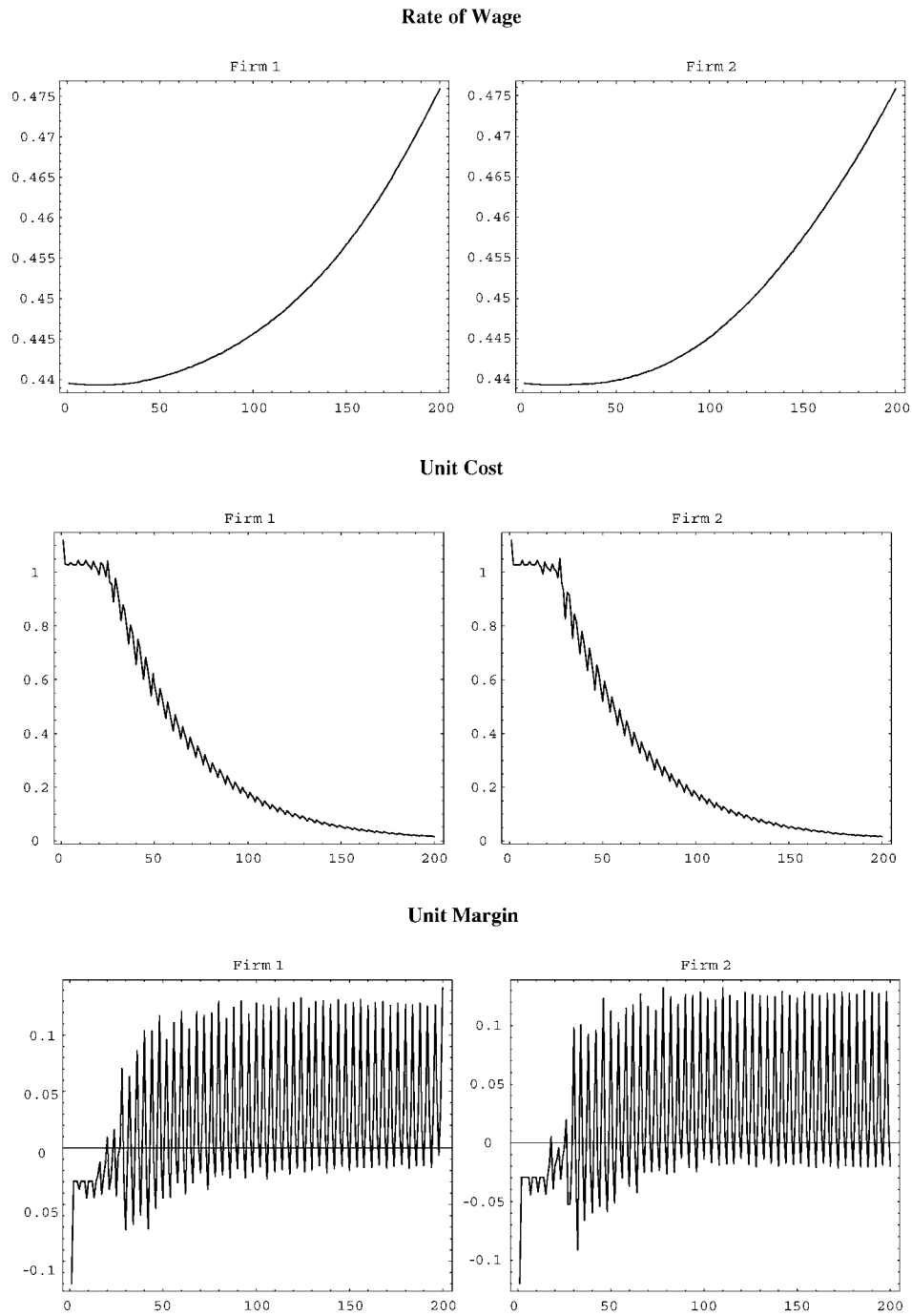


Figure 1. (Continued).

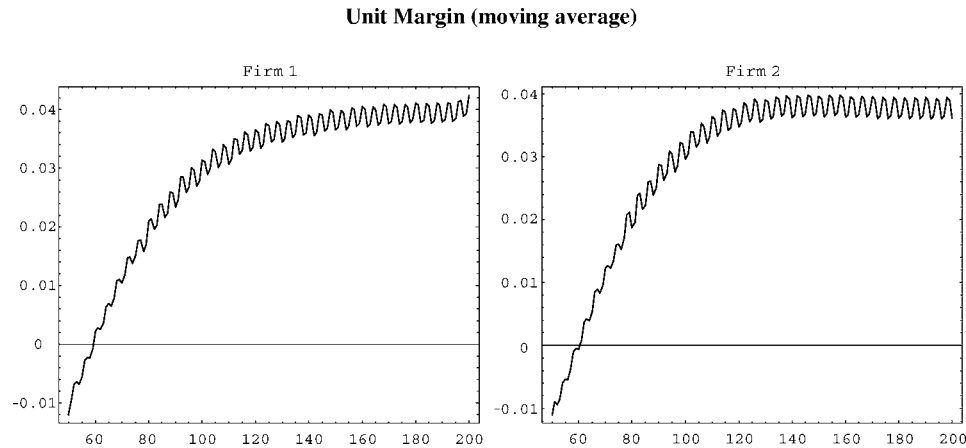


Figure 1. (Continued).

the very small fluctuations in market shares. On the other hand there is a full utilization of productive capacity and positive unit margins for both firms, due to the fact that there is under-investment as a whole with respect to the final demand.³

This means that conditions exist under which technical increasing returns are fully exploited by all firms, and that not only the firms themselves through increasing profits, but also the consumers through falling prices and the workers through rising wages, can take advantage of these returns.

What do the above results actually depend on? The performances of the firms depend on the frequency of technological shocks as well as on the external financial constraint—the borrowing power—which together contribute to determine the actual financial constraint. As a matter of fact the effective financial constraint—which appears as the most important means of co-ordination of the activity of the different firms—is the result both of the amount of external financing made available, as shown by the value of the parameter k and by the frequency of innovations which, by requiring more or less investment resources per unit of time, renders the above amount more or less adequate to what is needed.

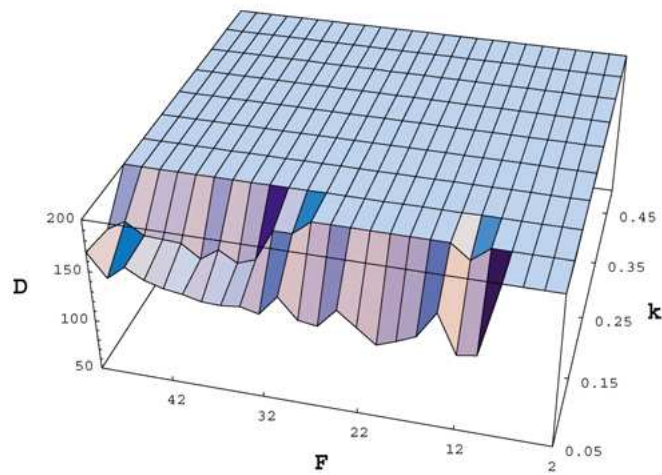
In order to analyze the role of the financial constraint we shall consider a number of runs corresponding to different values of the innovations frequency (F ranging from 2 to 50, which are the number of periods between successive innovations) and of the borrowing power (k ranging from 0.05 to 0.5). Three diagrams show what happens in terms of: (a) survival of the competitive market (as shown by the duration of the simulations D . The simulation is interrupted when one of the firms is obliged to exit from the market); (b) fluctuations in the market shares (measured by the variance σ and (c) behaviour of the unit margins μ . The comparisons will be done for different values of the wage rate reaction coefficient ($\nu = 0.001$, in Figures 2 and $\nu = 0.01$ in Figures 3).

The main results obtained are the following.

Let us start by the case considered in Figures 2. In this case the stronger the financial constraint, the higher are the unit margins for all frequencies of innovations. In the case of

Parameters	First shock	F	k	n	ν
Firm 1	5	$2 \rightarrow 50$	$0.05 \rightarrow 0.5$	10	0.001
Firm 2	15	$2 \rightarrow 50$	$0.05 \rightarrow 0.5$	10	0.001

Viability: Duration of Simulations (maximum = 200 periods)



Fluctuations in the Market Shares

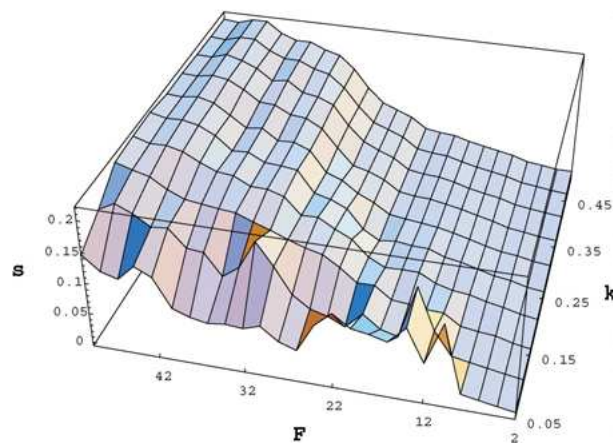


Figure 2.

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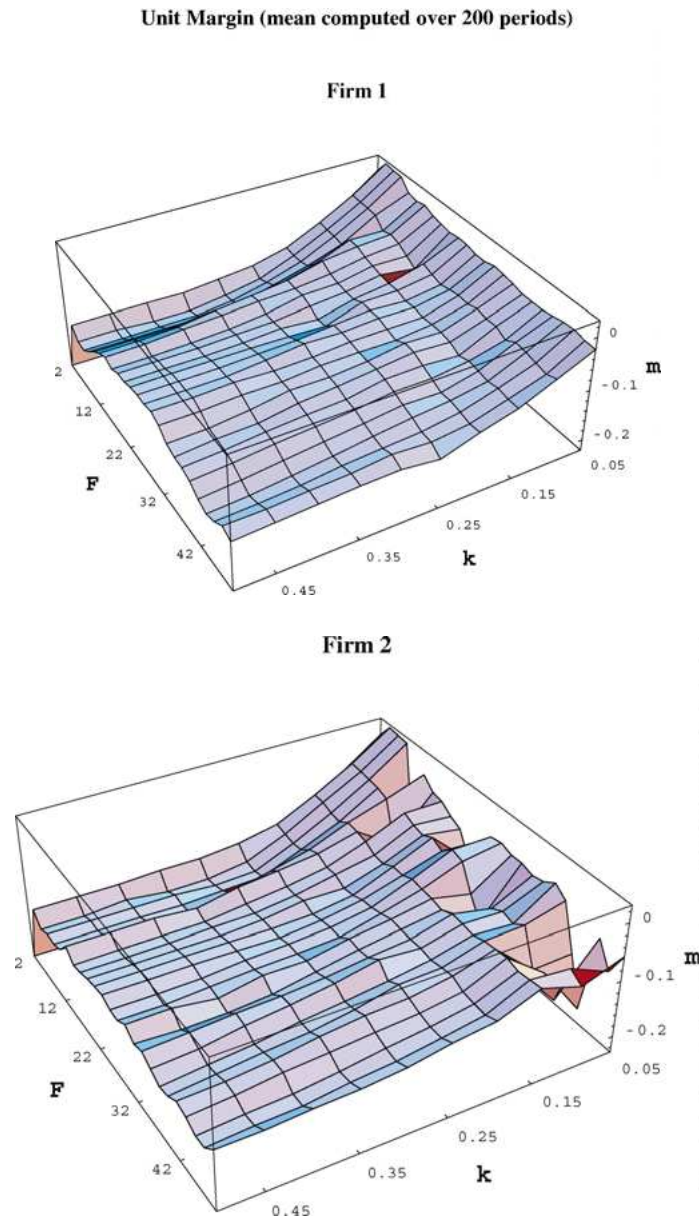


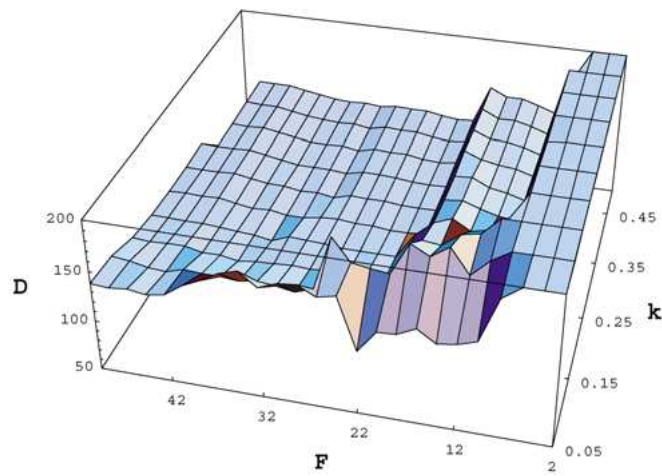
Figure 2. (Continued).

a very strong financial constraint (a very weak borrowing power), average unit margins are even positive for the higher innovations frequencies.

The simulations show that a strong enough external financial constraint helps the firms to be better co-ordinated with each other, by not allowing over-investment at the level

Parameters	First shock	F	k	n	ν
Firm 1	5	$2 \rightarrow 50$	$0.05 \rightarrow 0.5$	10	0.01
Firm 2	15	$2 \rightarrow 50$	$0.05 \rightarrow 0.5$	10	0.01

Viability: Duration of Simulations (maximum = 200 periods)



Fluctuations in the Market Shares

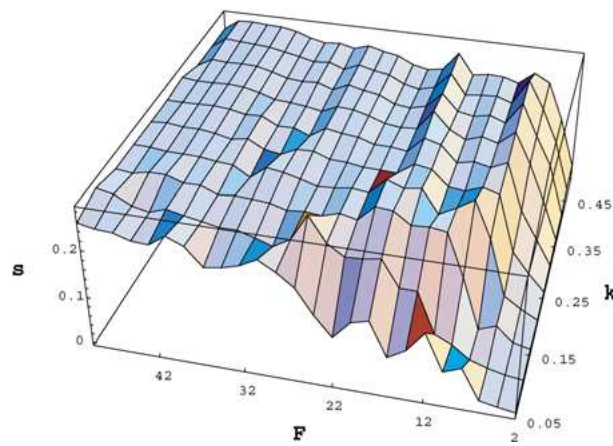


Figure 3.

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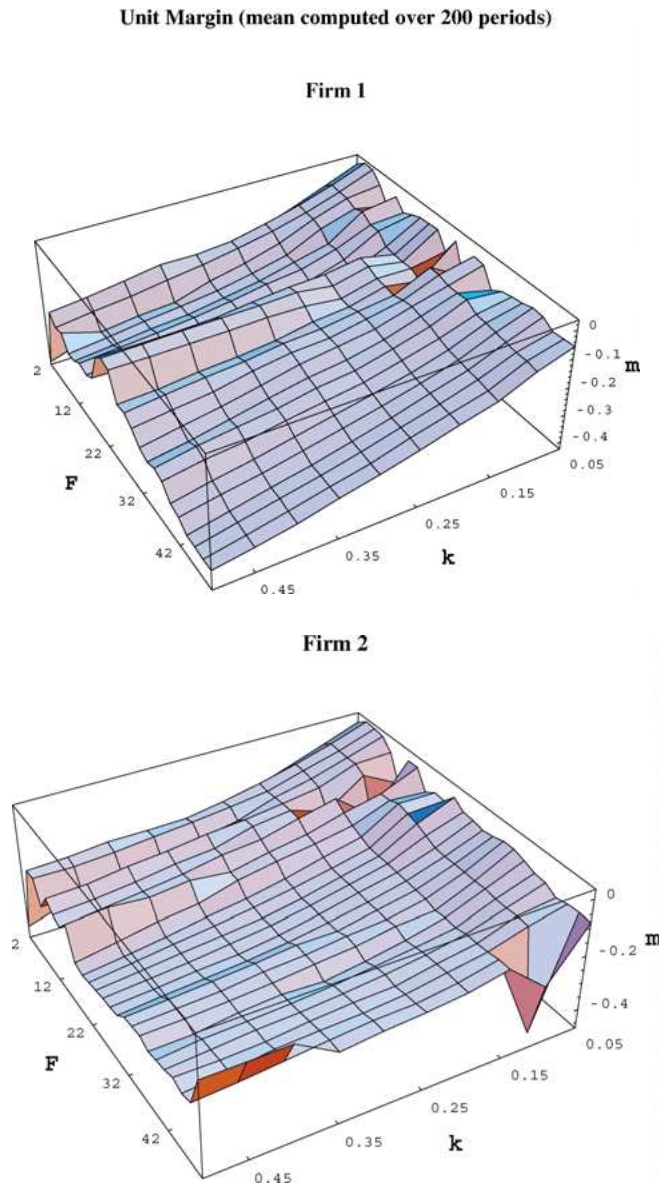


Figure 3. (Continued).

of the industry (an excessive ‘capacity competition’). When high innovations frequencies actually strengthen the existing financial constraint, the firms can even draw extra profits from innovations. In this case in fact, there is under-investment as a whole with respect to the investment that the firms intend to carry out to match the aggregate final demand; and this results in a full utilization of productive capacities and positive unit margins.

However, a strong external financial constraint is also a threat to the survival of competition as one of the firms may be obliged to exit from the market: in which case the simulation is interrupted.⁴ Then, for the reason just mentioned, only high innovation frequencies allow competition to be maintained.

Summing up. *The stronger the financial constraint the higher the unit margins, but also the greater the threat to competition unless innovations are very frequent.*

With a weak external financial constraint, average unit margins of both firms are negative whatever the frequency of innovations. They are strongly negative for both very high and very low innovations frequencies. As a matter of fact the firms cannot obtain positive unit margins when technological changes are very frequent because they have to bear heavy and above all increasing construction costs while (if so) they keep charging prices which correspond to 'normal profits' in a steady state structured by a given technology. There is not enough time for having sufficient returns to the successive investments in new technologies. On the other hand the main effect of a pronounced decrease in the frequency of innovations is to make less stringent the already weak financial constraint and hence to reduce both the level of utilization of productive capacity and the level of unit margins. Only intermediate values of the innovations frequency allow firms to better manage the profitability problems associated with the existence of sunk costs.

As to the effects on market shares *whatever the borrowing power of the firms, the lower the innovations frequency the stronger the fluctuations in shares.* As a matter of fact, high innovation frequencies prevent any firm from acquiring a competitive advantage over a long period, which would result in protracted gains in market shares.

Finally, let us consider the effects of wage flexibility by contrasting the case examined up to now with the case of a stronger wage reaction coefficient ($\nu = 0.01$ instead of $\nu = 0.001$). Figures 3, compared with Figures 2, show that a greater wage flexibility implies stronger fluctuations in market shares. As a matter of fact, in the case of a strong wage flexibility the prices charged by the firms do not decrease and, as a consequence, aggregate final demand is growing much more slowly. Moreover, the competitive advantage that initially result from productivity gains is rapidly counterbalanced by the increase of the wage rate. All these events result in a strong instability which makes the possibility of exit from the market random and does not allow the survival of a competitive market unless innovations take place very frequently (in which case both firms remain on the market whatever the external financial constraint).

These results are the expression of dynamic processes dominated by the tension between competition and innovation. Given in fact the expectations of an exponential growth of final demand, the innovative firms try to increase their productive capacity at costs which are expected to be falling as the result of the continuous innovation process. Clearly, the less stringent the external financial constraint the higher the investment that the firms can (and will) carry out. The 'capacity competition' between firms thus becomes stronger, while, at the same time, the production costs of the same firms are actually increasing since they do not depend only on current production but on the time profile of the production processes, which reflects the continuous flow of innovations characterized by continuously increasing construction costs. This implies negative unit margins for all firms. The way to increase the

unit margins is to reduce investments by strengthening the financial constraints. However, the expectation of an exponentially growing demand pushes bankers and the financial markets interested more in growing markets than in current profits to go on sustaining the investments undertaken by the firms even with negative unit margins. This is the story of the high-tech firms that supply the so-called technology shares on specialized financial markets (on the NASDAQ, e.g.) in the early phase of the industry life cycle. Whatever the nature of financial institutions, a sort of perverse incentive system may prevail, which associates easily available financial resources with negative unit margins. On the other hand, unit margins are also related to the frequency of innovations. The higher this frequency, the lower the fluctuations of market shares, and the higher the unit margins. Incentives exist for increasing the innovations frequency. In this context, the standard case in the simulations performed is that in which an innovations frequency high enough is combined with a not too strong external financial constraint which reveals the choice made by bankers or shareholders to support innovation in fast growing demand sectors. For a while unit margins are negative, but competition, fuelled by the available financial resources, is maintained.

7. Conclusion

When competition is seen as a process sketched out by the sequential interaction of competing firms which implies a continuous restructuring of productive capacities, problems of co-ordination come to the fore. Co-ordination with the environment where this process of restructuring takes place for the process itself to be viable and co-ordination between firms for the survival of competition. We have shown that the role of financial constraint, is essential for making this co-ordination possible.

There is a sort of trade-off between innovation and competition. Competition is the more likely to be maintained the more frequent the innovations, as this reduces the intervals during which firms may enjoy monopolistic power. On the other hand competition may entail lower or even negative unit margins (due to an excessive capacity competition) which induce firms not to innovate. The existence of financial constraints is required to co-ordinate the activity of competing firms as it prevents over-investment as a whole, and hence makes it possible positive unit margins. A high frequency of innovations to maintain competition should therefore be combined with a strong external financial constraint, while a competition process which generates positive unit margins favours innovation.

Notes

1. When this state is seen as the result of competitive behaviours, these are implicitly assumed to be no longer active. No further competition among the surviving firms is in fact possible, because, by definition, in this state "the effects of competition have reached their limits" (Cournot 1929:90).
2. This comes down to assume that the firms, unlike in the game strategic approach to the analysis of competition, do not know in advance the results of the market game. In fact no strategic consideration is made at all. This is so because competition has a sequential character. The fact that the firms innovate one after the other does not allow to define properly the market game at any given moment.
3. The consideration of the case of fix-wage does not modify significantly the results of the analysis of the impact of innovations on costs, prices and competition.

4. This is so when the lack of financial resources results in a scrapping of production processes such that the firm in question has no longer the capacity to supply the amount of final output corresponding to the current demand.

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